DEVELOPMENT OF ELECTROCOAGULATION CELL BY USING DIFFERENT TYPES OF ELECTRODE MATERIALS TO TREAT RESTAURANT WASTEWATER

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BACHELOR OF ENGINEERING TECHNOLOGY (ENERGY & ENVIRONMENTAL) WITH HONOURS

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We hereby declare that we have checked this thesis and in our opinion, this thesis is adequate in terms of scope and quality for the award of degree of Bachelor of Engineering Technology in Energy and Environmental.

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STUDENT'S DECLARATION

I hereby declare that the work in this thesis is my own except for quotations and summaries in which have been duly acknowledged. The thesis has not been accepted for any degree and is not concurrently submitted for award of other degree.

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ABSTRAK

Sel elektrokoagulasi (EC) adalah teknologi untuk mengurangkan bahan pencemar dari air sisa yang melibatkan arus elektrik ke dalam medium berair degan menggunakan elektrod. Penghasilan EC dengan menggunakan pelbagai jenis bahan elektrod untuk merawat air kumbahan restoran diselidik dalam kajian ini. Dua jenis bahan elektrod digunakan seperti Aluminium (Al) dan Besi (Fe) untuk menentukan keefisienan penyingkiran permintaan oksigen biologi (BOD), permintaan oksigen kimia (COD) dan jumlah pepejal terampai (TSS). Empat eksperimen telah dijalankan dengan menggunakan kombinasi bahan elektrod yang berbeza di anoda dan katod iaitu Al-Al, Fe-Fe, Al-Fe dan Fe-Al. Parameter operasi seperti jarak antara elektrod, tempoh rawatan, arus telah ditetapkan pada 10 mm, 120 minit dan 3 A. Keputusan penyingkiran tertinggi untuk BOD (98%), COD (91.4%) dan TSS (86.9%) telah diperolehi oleh Al-Fe di antara empat jenis elektrod. Sementara itu, pasangan elektrod terendah dicatatkan oleh Al-Al ialah 70.9%, 85.7% dan 64.4% untuk BOD, COD dan TSS. Selain itu, elektrod Fe-Al menunjukkan keputussan pengikiran 80.7%, 96.7% dan 63.0% untuk BOD, COD dan TSS. Akhir sekali, elektrod Fe-Fe mencapai penyingkiran keefisienan 80.6%, 95.7% dan 61.5% BOD, COD dan TSS. Hasil ini dapat dijelaskan oleh proses yang berlaku di anoda dan katod. Al memainlan peranan di anod kerana ia mengeluarkan ion trivalen (Al^{3+}) berbanding dengan elektrod besi yang menghasilkan ion divalent (Fe^{2+}). Cas positif yang tinggi mempunyai keupayaan yang lebih tinggi untuk mengurangkan kestabilan koloid. Selain itu, Fe lebih baik di katod kerana ia melepaskan banyak buih bersize kecil yang membantu dalam menghilangkan pepejal terampai dan membentuk pemberbukuan. Jumlah penghancuran Al adalah 0.102 g manakala Fe mencatatkan 0.801 g di mana Al melepaskan lebih banyak ion trivalen untuk membekukan pencemar dalam air kumbahan restoran. Keputusan eksperimen menunjukkan penyingkiran BOD, COD dan TSS yang efektif melalui cara EC dengan menggunakan elektrod Al dan Fe.

ABSTRACT

Electrocoagulation cell (EC) is a technology to remove pollutants from wastewater which involve electric current into an aqueous medium using electrode. Development of EC by using different types of electrode materials to treat restaurant wastewater was investigated in this study. Two types of electrodes materials were used such as Aluminums (Al) and Iron (Fe) to determine the removal efficiency of biological oxygen demand (BOD), chemical oxygen demand (COD) and total suspended solids (TSS). Four experiments were run out by using different combination of electrode materials at anode and cathode which were Al-Al, Fe-Fe, Al-Fe and Fe-Al. The operating parameters such as inter-electrode distance, treatment duration, current intensity were fixed at 10mm, 120 minutes and 3A respectively. The highest removal for BOD (98%), COD (91.4%) and TSS (86.9%) was obtained by Al-Fe among four electrode types. Meanwhile, the lowest electrode pairs were recorded by Al-Al with a value of 70.9%, 85.7% and 64.4% for BOD, COD and TSS respectively. Besides, Fe-Al electrodes showed a result of 80.7%, 96.7% and 63.0% of BOD, COD and TSS removal efficiency respectively. Last but not least, Fe-Fe electrodes achieved 80.6%, 95.7% and 61.5% efficiency removal of BOD, COD and TSS. This result can be explained by process occurred at anode and cathode. Al performed good at anode as it released trivalent ion (Al^{3+}) instead of divalent ion (Fe^{2+}) by iron electrode. Higher positive charge had higher ability to destabilise the colloids. While, Fe was better at cathode because it released small size but large amount of bubbles which helped in removing suspended solids and formed flocculation. The amount of Al dissolution was 0.102 g while Fe recorded 0.801 g which meant Al released more trivalent ion to coagulate the pollutant in restaurant wastewater. The experiments result showed efficient removal of BOD, COD and TSS by EC with Al and Fe electrodes.

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LIST OF SYMBOL

C	Concentration BOD, COD and TSS after treatment, mg/L
C_o	Concentration of BOD, COD and TSS before treatment, mg/L
F	Faraday constant (96485.3 C mol^{-1})
I	Current, A
M	Mass of anode dissolved, g
T	Time of operation, s
Z	Number of electrons donates in anodic solution process per mole of metal

LIST OF ABBREVIATIONS

AC	Alternating power supply
AD	Anaerobic digestion
Al	Aluminium
Aq	Aqueous
BOD	Biological oxygen demand
BP	Bipolar
COD	Chemical oxygen demand
DAF	Dissolved air flotation
DC	Direct current
EC	Electrocoagulation
Fe	Iron
FOG	Fats, oils and grease
G	Gas
HCl	Hydrochloric acid
IC	Internal combustion
MBAS	Methylene blue active substance
O&G	Oil and grease
POME	Palm Oil Mill Effluent
RDE	Restaurant dishwasher effluent
S	Solid
STE	Septic tank effluent
TOC	Total organic carbon
TSS	Total suspended solid

CHAPTER 1

INTRODUCTION

1.1 Background of Study

One of the most pressing challenges in the 21st century is providing sufficient clean water supply that is free from pollutants. In terms of humans, recent estimates reveal that there are 884 million people throughout the world who do not have access to clean and healthy sources of drinking water (Kristen E. Gibson, 2011). Poor access to clean water not only creates logistical problems for the people, but also makes them more disposed to many water borne diseases. Water is clearly one of the most basic of human needs, crucial to sustain all of life of human, animal and plant. Each person on Earth needs at least 20 to 50 litres of clean and safe water a day for drinking, cooking, and simply keeping themselves clean (National Academy of Sciences, 2007). Just like humans, plants and animals require water that is clean and moderately pure because they cannot survive if water is loaded with toxic chemical or harmful microorganisms.

Wastewater refers to water that has been used. It originates mainly from domestic, industrial, groundwater, and meteorological sources, and commonly referred to as domestic sewage, industrial waste, infiltration, and storm-water drainage. Wastewater from restaurants and other commercial food service differs significantly from residential wastewater. In addition to higher flow volumes during busy periods, and usually-higher temperatures, restaurant wastewater is normally higher in strength than residential wastewater. The direct discharge of wastewater from restaurants down the drain is a huge extra burden to the municipal wastewater collection and treatment works. The oil and grease contained in the wastewater amassed and foul the sewer system and produce an unpleasant odour (Chen et al., 2000).

Basically, restaurant wastewater treatment facilities must be highly effective in eliminating biological oxygen demand (BOD), chemical oxygen demand (COD) and total suspended solid (TSS). Low capital and operating costs are important because profit borders of most restaurants are small. In addition, the technology has to be simple so that it can be operated easily. Conventional treatment that can be used to treat restaurant wastewater are physical, chemical or biological treatment. Conventional biological processes are not suitable due to the requirement of large space, long residence time and skilled technicians. Chemical coagulation is not practicable because of the low efficiency in removing light and finely dispersed oil particles and possible contamination of foods by chemicals. The G-bag approach, which uses a bag of absorbent to capture the pollutants and degrade the pollutants with the immobilized microorganisms on the absorbent, seems to be a good alternative only if the system can be designed as simple and free from fouling (Chen et al., 2000).

Electrocoagulation (EC) has been suggested as an advanced alternative in pollutant removal of restaurant wastewaters. Electrocoagulation is a treatment process involve electric current into an aqueous medium in an electrochemical cell using an electrode (Malakangouda et al, 2016). At this point, the process has attracted a great deal of attention in treating various wastewaters because of its versatility and environmental compatibility (Ozyonar & Karagozoglu, 2011). The electrocoagulation process also is a simple equipment, easy operation, a shortened reactive retention time, no chemical additions, and decreased amount of precipitate or sludge, which sediments rapidly (Ozyonar & Karagozoglu, 2011).

Electrocoagulation was first suggested by Vik et al. describing a sewage treatment plant in London built in 1889 where electrochemical treatment was employed via mixing the domestic wastewater with saline seawater. In 1909, J.T. Harries received a patent for wastewater treatment by electrolysis using sacrificial aluminium and iron anodes in the United States (Vik et al., 1984). (Matteson et al., 1995) described the ‘Electronic Coagulator’, which electrochemically dissolved aluminium from the anode into the reaction solution that cooperated with the hydroxyl ions produced at the cathode to form aluminium hydroxide. The hydroxides flocculated and coagulated the suspended solids, purifying the polluted water. A similar process was used in Great Britain in 1956 (Matteson et al., 1995), in which iron electrodes were used to treat polluted river water.

Electrocoagulation has been tested successfully to treat potable water (Vik et al., 1984), textile wastewater (Demirci et al., 2015), slaughterhouse wastewater (Widiasa & Johari, 2010),

simulated quick service restaurant wastewater et al., 2014), restaurant wastewater (Chen et al., 2000) and tannery wastewater (Malakangouda et al., 2016). This process is characterized by a fast rate of pollutant removal, compact size of the equipment, simplicity in operation, and low capital and operating costs. Besides, it is more effective in treating wastewaters containing small and light suspended particles, such as oily restaurant wastewater, because of the additional electro-flotation effect. It is estimated that the electrocoagulation would be an ideal choice for treating restaurant wastewaters. Hence, the electrode factor is observe to study the effectiveness of the electrocoagulation process in order to reduce the concentration in retention of time.

1.2 Problem Statement

Most of the Malaysia's population tend to follow western lifestyle in which results in consumers are willing to dine at restaurants instead of dining at home (Dong et al., 2016). The amount of restaurant waste apparently increases with the increasing number of restaurants in town. The owners of restaurants discharge the waste directly into the drains near to their restaurants. Therefore, the rivers nearby are polluted by the restaurants waste. Department of Statistic Malaysia show that food service establishments (FSE) alone accounted for 192, 710 sources of pollution identified in 2012. The main pollutants in rivers are biological oxygen demand (BOD), chemical oxygen demand (COD) and total suspended solids (TSS). Moreover, restaurant wastewater contains high BOD, COD and TSS which pose serious harm to environment and human health. Next, TSS reduces water turbidity and light penetration. As a result, photosynthetic process of micro plants in rivers is reduced. Not only that, it also will lead to bad odour but potential pipe failure. Besides, high BOD and COD concentration affect the deoxygenating which threaten the aquatic life and limit the clean water source (Singh et al., 2014).

In addition, the pollutants can be neither simply treated conventionally nor decomposed biologically due to their consistency. Besides, conventional treatment of restaurant wastewater takes longer time to be treated. Other than conventional biological treatment, chemical coagulation settlement also not practicable because it is not efficient in removing light and finely dispersed oil particles by chemicals (Xu et al., 2004). However, among all the methods of treating restaurant wastewater, electrocoagulation is better and effective method to treat restaurant wastewater.

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